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xiaoyu Wang

Huazhong University of Science and Technology, Wuhan China

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A study on the "inverted U" relationship between open innovation and enterprise innovation capacity

Wang xiaoyu

Huazhong University of Science and Technology, Wuhan China

Abstract: Innovation is the core motivation of the economic development, while the open innovation model provides our country enterprise an opportunity to improve the innovation capability. The implementation of the open innovation improve the enterprise innovation capacity, for it makes the enterprise can effectively integrate internal and external innovation resources, constructs a new innovation system and reduces the uncertainty in the process of innovation. However, excessive open will increase the transaction cost of enterprises, excessively depend on external resources and improve the probability of core technology leakage. All these are not conducive to the promotion of enterprise innovation capacity. This thesis makes an empirical analysis by using the Pearson correlation coefficient. The result shows that the open innovation and enterprise innovation capability is "inverted U" relationship.

Keywords: open innovation; enterprise innovation capacity; Pearson correlation coefficient

1. CLPSED INNOVATION TO OPEN INNOVATION

With the development of global economic integration and the explosion of information technology, competition among the countries tends to be the competition of science and technology, which ultimately reflected in the national innovation ability. Innovation has become the main melody of the new century. In today's society, the innovation provides exhaustible driving force to the country's development, and it has become the soul of national progress. A country can't stand on the world without innovation, and a nation will have no hope without innovation. National innovation reflected in the innovation of the enterprise finally, and the analysis about the enterprise's innovation will contribute to a better understanding of innovation and the implementation of innovative activities. As the micro individuals of the country, enterprises' innovation ability directly decides the national innovation ability. The traditional idea believes that innovation is the key of enterprise competition in the market. In order to avoid the outside world has access to the innovations, the enterprise only can rely on its own strength to carry out innovation activities, and the innovative activities have to be strictly confidential. As a result, the traditional innovation is dispersed, closed, and all kinds of innovation factors lack of mobility. Some large enterprises such as DuPont, General Motors, and IBM, will spend a lot of money every year on hiring creative talents in the world for basic research. It turns out that the investment these large enterprises made finally pay out. The science and technology personnel made a lot of breakthrough research every year, and the enterprise design new products according to the research results and commercialized, which was a great success and brought profit to enterprise. Once the enterprises have enough profit, they will further increase R&D investment in order to get more new innovations, forming a virtuous circle, and that is the closed innovation. Shortly speaking, closed innovation is that the whole activity of innovation is limited in the interior of the enterprise.

However, in the late 20th century, the great changes have taken place in the environment of enterprises were facing. First of all, the enterprise innovation investment return rate began to reduce, which seriously affected the enterprise's competitive ability. Secondly, some important innovations did not match the enterprise business, and then had been put aside which caused the waste of resources. In the 1980s, some enterprises which did not have strong research ability at first has begun to have strong innovation ability, and brought huge

competition pressure to the old research enterprises. The changes gradually disintegrated the basis of these closed innovation: (1) with the rapid development of information technology, the enterprise has no long-term had sophisticated technical personnel, and the number and frequency of talent flow has speed up a lot; (2) the external awareness of innovation got increasingly strong because of the education popularization; (3) the rapid development of venture investment company makes part of the enterprises original lack of research equip with the research and development ability, thus fierce their competition between the established enterprises; (4) the product life cycle continuously shortening, so the enterprise internal and external cooperation demand has become more and more urgent. Under the influence of these factors, open innovation arises at the historic moment.

In 2003, American economists Chesbrough (2003) ^[1] proposed open innovation mode. Open innovation refers to the use of enterprise internal and external market channels to proceed innovation activities. Under the condition of open innovation, innovative ideas can come from internal research and development department, and may also be from outside of the enterprise. That is to say, the enterprises can use their own ability to innovate, and also can get external innovation through the way of buying. Chen Jin and Wu Bo (2012) ^[2] believe that one of the main purpose enterprises implement open innovation is to obtain key resources the innovation needed in order to enhance the competitiveness of the enterprises. In reality, however, it is hard to make every enterprise be willing to or implement open innovation, an important reason of which is that the influence of open innovation on the enterprise innovation ability has certain uncertainty, and this uncertainty is characterized by uncertainty of immediate effect, which also perform as the uncertainty of longer period of time. The evaluation of the affection in a cycle or a phase of open innovation on the enterprise innovation ability became the starting point of this research.

2. MODEL CONSTRUCTION

2.1. Hypothesis 1: open innovation accelerates the enterprise innovation ability promotion

Under the open innovation mode, the enterprise's boundary is open, as for the technology intensive enterprise, the scale of which is larger, and constantly has its own independent research and development team and wide market resource; in the meanwhile, it always contacts with the outside world a lot. This ensures that the technology intensive enterprises can obtain the thoughts and ideas enterprise innovate needed from both the internal departments and outside of the enterprise, that is the most fundamental distinction between open innovation and the traditional closed innovation. Technology intensive enterprises focus on technology and can get the organization's external support for innovation in time in the process of research and development. In an open mode, the innovation of the enterprise has become a global activity. Open innovation mode can be thought to be the multi-agent innovation model which is linked by interests, and manifested in the absorption of innovation elements and the increase of the innovation main body.

The enterprise innovation ability can be promoted through enterprise external access to the needed innovative ideas and technology ^[3]. Create within the enterprise and obtain external resources are the two ways to create value for enterprises. For enterprise, the uses of external valuable ideas and technology resources have 3 advantages: (1) it can save the funds required to research and develop on its own; (2) it can shorten the development cycle; (3) it can improve the efficiency of innovation ^[4]. Enterprises can have access to external innovation resources by cooperating with external organizations, and mutual cooperation between different innovation main bodies can realize joint adventure and resources sharing, through the complementary advantages between innovation subjects, and also can shorten the innovation cycle, while improving the efficiency of innovation ^[5]. In addition, the cooperation between innovation subjects in the different fields can produce technological breakthroughs, creating new technology ^[6]. In general, on the basis of its own research

and development ability, the enterprise can track the all kinds of market information in time, and choose other innovation main body building dynamic relationships according to their comparative advantage, which can reduce the uncertainty of the innovation process, save cost and improve the efficiency of innovation.

Open innovation mode is another important type to commercialize the enterprise internal innovation by external means. Under the closed innovation mode, part of the enterprise innovation has not been used, and caused the waste of resources. Under the mode of open innovation, by outputting innovation products, on the one hand, enterprises can accurately measure the value of innovation, and provides the judgment basis for the further investment; on the other hand, innovation can improve the loyalty of employees, since the products is filled with employees' hope, output enterprise innovation products will give the researchers a sense of achievement, which can reduce the likelihood of staff turnover, and stimulate the enthusiasm of staff study, which was beneficial to the improvement of the enterprise innovation ability. Enterprises will get a patent technology or transfer fee when exporting innovation products, which can improve the business income, promote the influence of the enterprise technology and expand enterprise's popularity. Open innovation is the process which can integrate enterprise internal and external resources effectively, build the new innovation system, reduce the uncertainty in the process of innovation, and improve the innovation ability of enterprises.

2.2. Hypothesis 2: open innovation restrains the enterprise innovation ability promotion

After adopting open innovation mode, enterprises can achieve the purpose of improving the efficiency of innovation through the integration of internal and external innovation resources, but excessive open to the outside does not favor the promotion enterprise's innovation ability.

Opening to the outside causes cost. Williamson (1981)^[7] believed that the opportunity cost and financial cost is the major cost of enterprises' external connection. Compared with the closed innovation, open innovation mode will generate information search cost and transaction cost. The major purpose enterprise implementation of open innovation is to use external resources, specifically speaking, enterprises need to follow the market development direction, timely find the enterprise match technology and the right partner, and that all will generate external information search costs. There is information asymmetry between enterprise and technology owner, as a result, enterprises need to spend time and energy to communicate with partners, and identify the feasibility of the technology transfer through their own strength, which all will generate the trading cost. Open innovation is multi-organizations innovation mode, since different organizations have different enterprise values, cultural viewpoint and organizational goals, in order to reduce the opportunism behavior appeared in the process of cooperation and ensure the smooth operation of the cooperation, enterprises have to spend extra effort and time to supervise the performance behavior of partners, and this will increase the transaction cost.

Nowadays, the technology enterprises needed has become more and more complex, and the market is filled with all kinds of information, so the uncertainty which innovation project facing keeps increasing. In order to reduce the uncertainty of innovation activities, enterprises need more information. But the enterprise can generate new uncertainty in the process of connecting external while searching for information^[8]. With the increase of technological complexity, enterprise technology alliance innovation has to face greater risk. Mckinsey's study shows that 70% of technology alliance was forced to dissolve because of the failure to achieve the desired initial goals. Once the alliance dissolved, the previous efforts the alliance had done for innovation activities would be useless^[9], in other words, open innovation has opportunity cost, and the opportunity cost is quite high.

Excessive search and obtain external resources are not conducive to the improvement of enterprise innovation ability^[10]. Enterprise need the matched knowledge absorptive capacity to convert internal external resources into internal innovation products^[11], in general, the enterprise has a certain absorptive capacity, once

enterprises absorb external resources that exceed the absorption and transfer ability, namely more than the enterprise can bear, then the excess external resources will diversify the enterprises' attention, and go against the centralized configuration of resources. Introducing too much external resources will seriously affect the enterprise's own research and development ability, and causes the enterprise inertia rely on external resources ^[12], and subject to partner on the core technology.

The biggest challenge faced by enterprises during the open innovation implementing process is technology leaks. Enterprise's partners include potential competitors and non competitors, although the cooperation with the non competitors generates certain information leakage, the leak problem in the process of cooperation with potential competitors is what that matters, which is also the preventing point ^[13], since the competitors can access to sensitive business information and technical knowledge through the common suppliers and users.

In general, enterprises adopt open innovation mode to absorb external resources can produce search cost and transaction cost, while the excessive openness caused the enterprise inertia rely on external resources, which may generate core technology leaks. Therefore, the excessive openness would go against the increase of innovation ability. There is "inverted U" relationship between the openness and enterprise innovation ability (as shown in figure 1), besides, Laursen (2004) ^[14] and Chen Yufen (2007) ^[15] support this view.

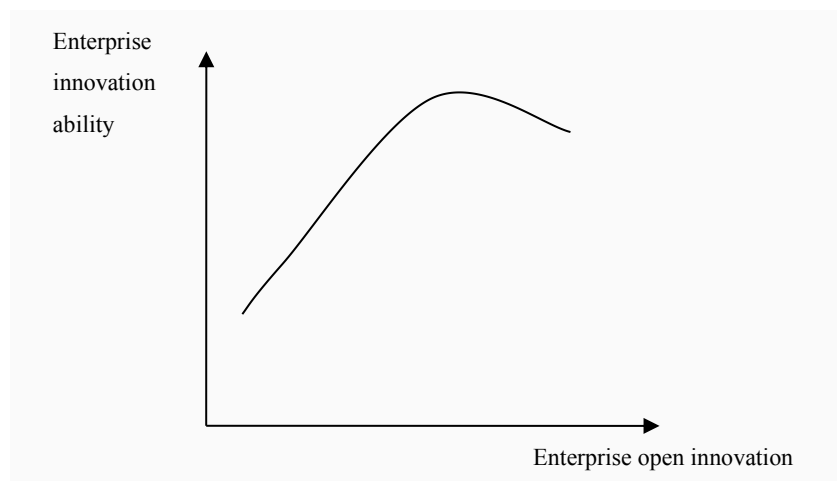


Figure1. The relationship between enterprise open innovation and innovation ability

3. EMPIRICAL ANALYSIS

3.1. Data collection and processing

3.1.1 The source of the data

Because the thesis is mainly aimed at technology-intensive enterprises, and part of the data involved in the company's core information is difficult to get through public channels. Therefore, the thesis made a questionnaire, and it was sent to all kinds of technology intensive enterprises via email according to the alumni directory in a total of 250 copies, with the support of alumni, author received 131 replies, the recovery rate was 52.4%. In addition, after sending 150 copies of print and electronic questionnaire to the MBA students, author received 117 replies, the recovery rate of which was 78%. Author also sent 100 copies to some enterprises via email and received 13 replies, the recycle rate of which was 14%. To sum up, there are a total of 500 questionnaires were sent out, and the recovery rate was 52.6%, but there are 34 questionnaires were invalid because of the lacking of some data, namely there were 229 valid questionnaires, in other word, the efficient rate of which was 45.8%.

3.1.2 Measurement of enterprise innovation ability

Because of the data finding problem, most scholars use enterprise patent as the representative of the

enterprise innovation ability. But in technology intensive enterprises, part of the proprietary technology exists in enterprise staff's knowledge, which cannot be patented, and is unable to accurately measure, while some part of the technology is confidential for secrecy need, which cannot be used to apply patent, therefore some scholars believed that the patent and the proprietary technology the enterprises have as a representative of the enterprise innovation ability. In view of this, the thesis chooses the enterprise owned proprietary technology and patent as a measure of enterprise innovation ability.

3.1.3 Measurement of enterprise openness

The essential of the enterprise openness is to contact with the outside world for resources. Laursen and Salter designed the questionnaire to measure the effect of openness on the enterprise innovation performance, and to distinguish the enterprise's breadth and depth of the open innovation. The breadth refers to the cooperation types between enterprises and external innovation resources, and external innovation resources include customers, suppliers, competitors, non-technical related enterprises, institutions of higher learning, scientific research institutions, technology intermediary agencies, intellectual property rights institutions, risk investment institutions and government. Depth refers to the times enterprise cooperates with every kind of the external innovation resources. The author uses the concept of open innovation depth as a measure of open innovation degree.

3.2. Model test

3.2.1 Statistical analysis

Firstly, the thesis uses SPSS17.0 to conduct the simple descriptive statistics for the enterprise external innovation resources. The result shows that within all the external innovation resources, which are customers, suppliers, competitors, non-technical related enterprises, institutions of higher learning, scientific research institutions, technology intermediary agencies, intellectual property rights institutions, risk investment institutions and government, the uses are the most important external innovation resource, in other words, users play an important role in the enterprise innovation process. After knowing the basic information of the enterprise external innovation resource, the reliability was conducted, and the result show that the alpha value of the questionnaire is 0.843, therefore, the consistency degree of the questionnaire reached the acceptable levels.

Then the author uses factor analysis method to conduct the validity test, and the KMO (Kaiser-Meyer-Olkin) and Bartlett (Bartlett Test of Sphericity) is the most common method. KMO value is between 0 and 1, if the value is close to 1, then the simple coefficient square sum of all variables is far bigger than partial correlation coefficient, namely it is fit for factor analysis, if on the contrary, it is unfit for factor analysis. Bartlett sphere test is mainly according to the determinant of correlation coefficient matrix to get correlation coefficient, and then analyze the correlation coefficient, if KMO value is relatively big, the corresponding concomitant probability value will be less than the significance level in the user heart, which means that there is a correlation between the original variables, and is suitable for factor analysis, on the contrary, it will be unfit for factor analysis. And the result shows that all the listed influence factors in this questionnaire have passed the reliability test, that illustrate the impact of open innovation on the enterprise innovation ability is credible. In validity test, after conducting the KMO and Bartlett sphere test, the results show that all the influence factors passed the KMO and Bartlett sphere test, and all the common degree of all the affecting factors are greater than 0.5, which means that the influence of open innovation on the enterprise innovation ability is effective.

3.2.2 Relationship analysis

First of all, the author uses SPSS 17.0 to analyze the linear correlation coefficient of open innovation and enterprise innovation ability, and the results show that the Pearson correlation coefficient of open innovation and

enterprise innovation ability is 0.641, which means that there is a strong connection between open innovation and enterprise innovation ability. Then, based on the former analysis, the author uses SPSS 17.0 conducted nonlinear regression analysis, where the open innovation is used as independent variable, while the enterprise innovation ability as the dependent variable and the result is show in table 1.

Table 1 Pearson regression analysis

Explanatory variables	Enterprise innovation ability
constant	-1.620 (0.320)
Enterprise open innovation	0.483 (0.067)
Enterprise open innovation ²	-0.232 (0.001)

Note: It is the significant probability P value given in parentheses.

4. CONCLUSION

As shown in table 1, the coefficient of open innovation and the innovation ability is 0.483, and the significant probability is 0.067, which passed the inspection under the significance level of 10%. The coefficient of square of open innovation and innovation ability is -0.232, and the significant probability is 0.001, which passed the significance level of 1%. Therefore, the relationship between open innovation and enterprise innovation ability is quadratic curve: the enterprise innovation ability will gradually improve when the degree of enterprises open innovation is small, but with the enlargement of open degree, enterprise innovation ability will became smaller after reached a turning point, while being in the downward bending part, then the whole curve presents the typical "inverted U", supported by the former theoretical analysis. Accordingly, the enterprise should keep moderate open proposition, which is to say that the enterprise innovation mode should not be too close or too open. In order to maintain the positive influence of open innovation on the enterprise innovation ability, and avoid or reduce the negative effects of open innovation may bring, the enterprise has to adjust the external development strategy and internal management system according to the characteristic of open innovation.

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